EVALUATION OF AN ELECTRIC, RADIANT-HEAT, QUARTZ OVEN

Robert L. Bernazzani, et al

Army Natick Laboratories
Natick, Massachusetts

January 1973

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
U S Army Natick Laboratories
Natick, Massachusetts 01760

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
Evaluation of an electric, radiant-heat, quartz oven.

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Technical Report

5. AUTHOR(S) *(First name, middle initial, last name)*
Robert L. Bernazzani, Robert L. Blais, Paul A. Bows, and Keith A. Kornuta

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1973	~~31~~ 28	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	74-8-GP
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U S Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

The radiant-heat quartz oven was evaluated to determine its ability to rapidly heat small quantities of pre-cooked frozen food and its acceptability as a backup oven in the satellite dining facilities of the centralized food preparation system concept. The oven was evaluated from a mechanical, food production, sanitary, and safety viewpoint and found to be satisfactory for heating pre-cooked food items in small quantities. Reheating time was less than half that required in large capacity convection ovens.

Product appearance was good; cleaning was easily accomplished; and there were no safety hazards noted.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Evaluation	8		8			
Safety	8					
Cleaning	8					
Sanitation	8					
Ovens	9					
Quartz	0					
Electrical Cooking Devices	9					
Kitchen Equipment & Supplies	9					
Military Feeding	4					
Military Rations	4					
Acceptability			8			
Food			9		9	
Reheating			9		10	
Thawing			9		10	
Food Preparation			9		8	
Production (Food)			4		4	
Garrison Feeding			4		4	
Marketing			4		4	

FOREWORD

The need for an oven to rapidly heat small quantities of pre-cooked frozen foods exists in the satellite dining facilities of the centralized food preparation system concept. The oven would be used as a backup to the convection ovens presently being used.

Acknowledgement is given to personnel of the Engineering Evaluation Office and the Food Service Equipment and Evaluation Team, Food Systems Equipment Division, General Equipment & Packaging Laboratory, for testing of the oven.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EVALUATION OF AN ELECTRIC, RADIANT-HEAT QUARTZ OVEN

1. Introduction

An electric, radiant-heat quartz oven* was evaluated to determine its ability to rapidly thaw and reheat pans of precooked frozen food and its acceptability for use in the satellite dining facilities of the centralized food preparation system concept. The evaluation encompassed design, food production, safety, sanitation, and confirmation of food preparation findings of commercial testing agencies.

2. Description of Oven

The oven is a one-compartment countertop model measuring approximately 86.36 centimeters (cm) (34 in.) wide by 35.56 cm (14 in.) high by 48.26 cm (19 in.) deep with an oven cavity suitable for holding the full-size 10.16-cm (4-in.) deep steamtable pan. The oven has two quartz plates forming the top and bottom surfaces of the oven cavity. The radiators are resistance coils mounted above an upper horizontal quartz plate and below a lower horizontal quartz plate. The control element is a thermostat bulb lying between the top coils and the upper quartz plate. The heating elements radiate extremely short heat waves that cover the entire surface of the food and pan. The oven cavity attains very high temperatures and outer surface temperatures are lowered by an automatic fan (Figure 1) that is triggered by a thermostat located in the space between the control panel and the oven cavity. Oven temperature is automatically controlled by an adjustable thermostat with a cooking temperature range from 121 1°C (250°F) to 398.9°C (750°F). A 454.4°C (850°F) setting is also provided for self-cleaning the oven cavity. A timer with settings from 0 to 15 minutes is also provided adjacent to the oven control and is a manually set item equipped with a buzzer. It does not have any control over the cooking operation and is used with the cooking charts included in the operator's manual. The cooking charts detail various foods in terms of their package weight, food thickness, and initial temperature with the corresponding settings and cooking times to be used with the oven. The oven is designed for operation on a 230-volt, 60-Hertz, 1-phase, a.c. power supply.

*A product of Groen Division, Dover Mfg. Co., Elk Grove, Ill. - Model No. 1001

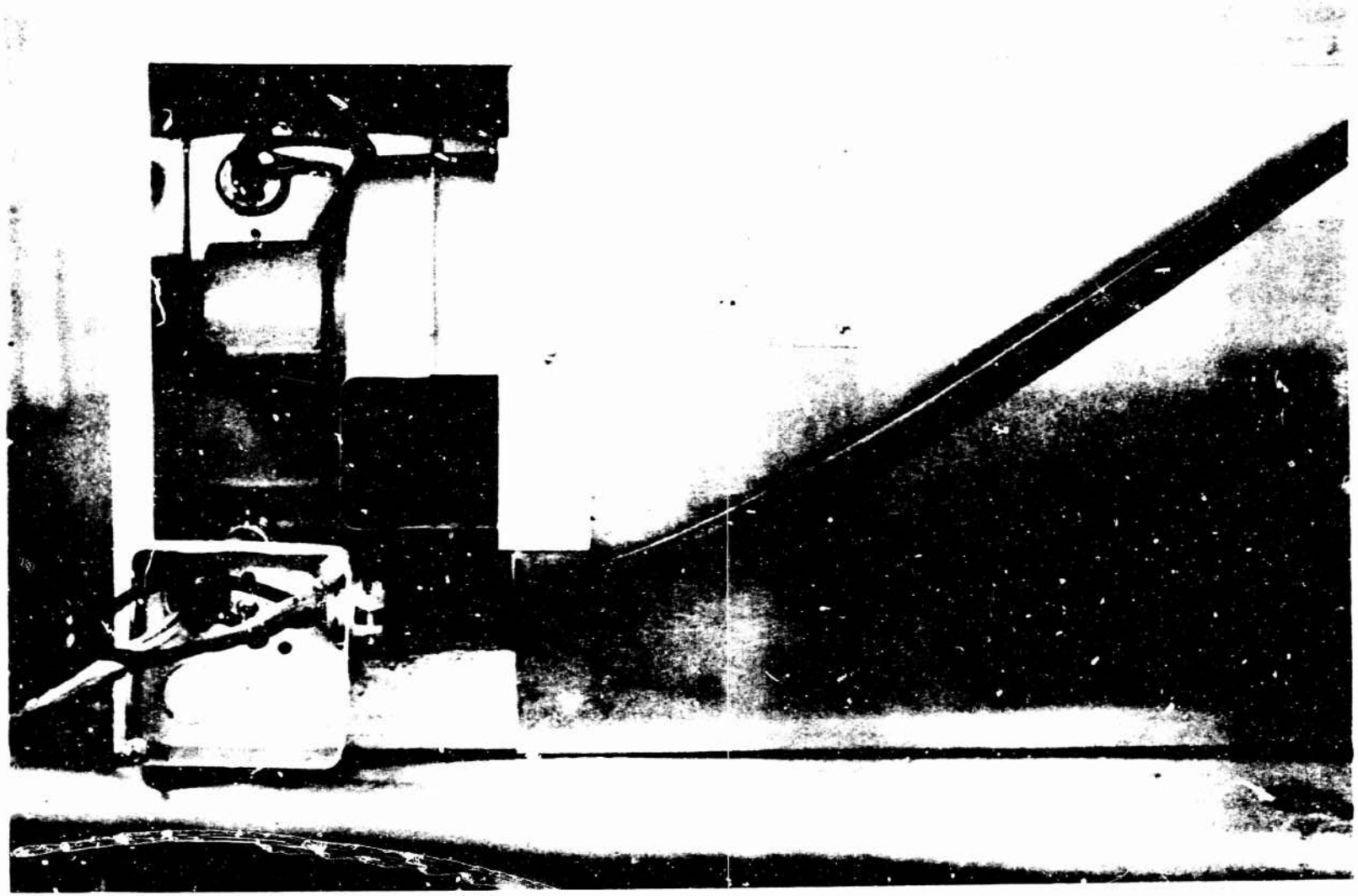

Figure 1. Back View, Cooling Fan.

3. Design Tests

a. Test Requirements:

(1) The oven was evaluated for the following design characteristics:

(a) Oven Heat Distribution
(b) Initial Heat-Up Time
(c) Outer Surface Temperature
(d) Timer Accuracy
(e) Control Performance
(f) Voltage Comparison Between 208 and 230 Volts

b. Test Procedures:

(1) The tests were conducted with the oven wired directly into a 208-volt, 60-Hertz, 1-phase line since this is the standard voltage at most military bases. All tests were conducted under an exhaust hood in ambient conditions varying between 21.1°C (70°F) and 26.6°C (80°F).

(2) Oven Heat Distribution

A heat distribution pattern was determined at thermostat settings of 350, 500, and 700 through the use of five thermocouples distributed in one plane equidistant from the top and bottom of the oven cavity. Thermocouples were numbered as indicated on Figure 2 and were positioned as shown on Figure 3 with Sauereisen sealing cement. The pattern included maximum, minimum, and average temperatures (Table I) at all five thermocouple locations, as well as fluctuations in temperature due to cycling (Table II).

(3) Initial Heat-Up Time

The interval between the time the oven was turned on and the moment the thermostat light went off was recorded by a stopwatch and considered to be the initial heat-up time. The maximum and minimum heat-up times were recorded and the averages computed for dial settings of 350, 500, and 750. The results are as shown on Table III.

Figure 2. Front View of Thermocouple Locations, Oven Open.

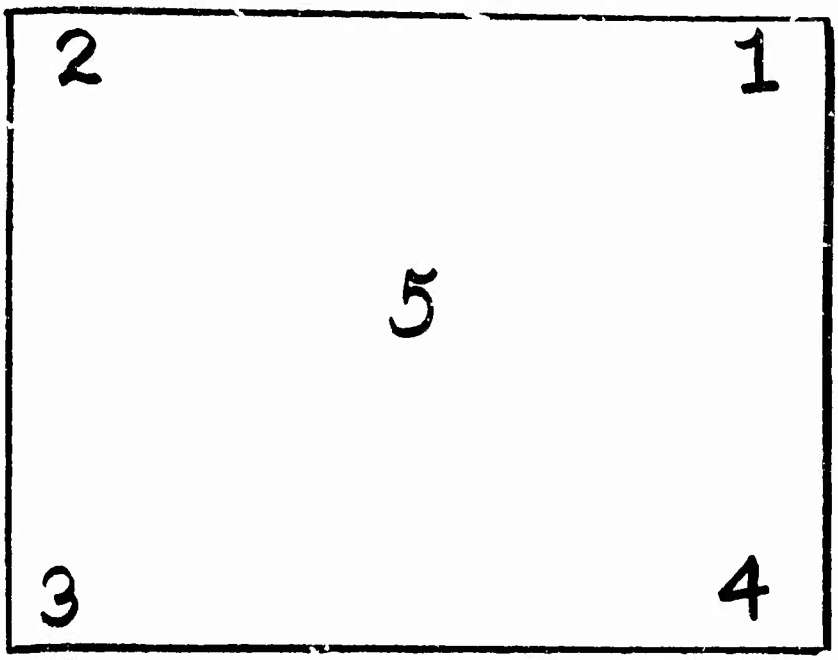

Figure 3. Top View of Oven Cavity Thermocouple Locations.

TABLE I. AVERAGE OVEN TEMPERATURES

Thermostat Setting	Avg. Oven Temp.	Max. Temp. at Thermocouple Location 5	Min. Temp. at Thermocouple Location 4	Average Temperatures				
				T.C. 1	T.C. 2	T.C. 3	T.C. 4	T.C. 5
350	182.8°C (361°F)	203.3°C (398°F)	165.5°C (330°F)	183.3°C (362°F)	185°C (365°F)	180°C (356°F)	176.7°C (350°F)	187.8°C (370°F)
500	255.5°C (492°F)	289.5°C (553°F)	201.7°C (395°F)	257.8°C (496°F)	262.8°C (504°F)	253.4°C (488°F)	241.6°C (467°F)	262.9°C (505°F)
750	380.5°C (717°F)	422.3°C (792°F)	338.8°C (642°F)	387.8°C (730°F)	392.8°C (739°F)	368.4°C (695°F)	360.6°C (681°F)	380.5°C (717°F)

NOTE: See Figure 3 for locations of thermocouples.

TABLE II. TEMPERATURE FLUCTUATIONS DUE TO CYCLING

Thermostat Setting	Thermocouple 1 High	Thermocouple 1 Low	Thermocouple 2 High	Thermocouple 2 Low	Thermocouple 3 High	Thermocouple 3 Low	Thermocouple 4 High	Thermocouple 4 Low	Thermocouple 5 High	Thermocouple 5 Low
350	198.8°C (390°F)	171.1°C (340°F)	203.3°C (398°F)	168.3°C (335°F)	197.7°C (388°F)	165.5°C (330°F)	187.8°C (370°F)	165.5°C (330°F)	201.7°C (395°F)	178.9°C (354°F)
500	277.8°C (532°F)	225°C (437°F)	283.8°C (543°F)	233.4°C (452°F)	272.7°C (523°F)	222.3°C (432°F)	262.9°C (505°F)	202.7°C (397°F)	282.2°C (540°F)	226.7°C (440°F)
750	420°C (788°F)	366.6°C (692°F)	421.1°C (790°F)	372.3°C (702°F)	393.4°C (740°F)	339.4°C (643°F)	338.8°C (732°F)	340.5°C (645°F)	422.3°C (792°F)	372.3°C (702°F)

TABLE III. INITIAL HEAT-UP TIME

Thermostat Setting	Maximum Heat-Up Time	Minimum Heat-Up Time	Average Heat-Up Time
350	10 min - 33 sec	10 min - 7 sec	10 min - 22 sec
500	16 min - 10 sec	15 min - 12 sec	15 min - 39 sec
750	25 min - 17 sec	23 min - 54 sec	24 min - 46 sec

(4) Outer Surface Temperatures

The maximum outer surface temperatures were measured by a Barnes Engineering IT-4 Thermal Master Non-Contact Infra Red Thermometer. Temperatures were taken at dial settings of 350, 500, and 700 and results are as shown in Table IV. The seven prescribed locations were:

The front of the top surface.
The door handle.
The door.
The left side.
The front section directly above the door.
The front section directly below the door.
The control panel.

(5) Timer Accuracy

Timer accuracy was checked by use of a stopwatch at settings of 5, 10, and 15 minutes. Accuracy results are as shown in Table V.

(6) Controls

The oven was allowed to cycle three times on and off, and the thermostat signal light was observed. The on-off switch was operated and the switch and switch light observed for proper operation.

(7) Voltage Comparison

The oven was operated on a 208-volt and a 230-volt power supply, and heat-up times and temperatures were recorded. Results are as shown on Figure 4.

c. Test Findings:

(1) Oven Heat Distribution

The minimum temperature was always at thermocouple 4 (front right corner) with the maximum temperature being at the geometric center, or thermocouple 5. The average temperatures at all thermocouple locations are listed in Table I. The temperature variation due to cycling was about 22.22°C (40°F) at each thermocouple in the 350 setting with a change of 55.56°C (100°F) at the 500 and 750 settings (Table II).

TABLE IV. MAXIMUM OUTSIDE SURFACE TEMPERATURES

Thermostat Setting	Front Top Surface	Door Handle	Door	Left Side	Above Door	Below Door	Control Panel
350	35°C (95°F)	29.44°C (85°F)	35°C (95°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	29.44°C (85°F)
500	35°C (95°F)	29.44°C (85°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	29.44°C (85°F)
750	37.78°C (100°F)	29.44°C (85°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	29.44°C (85°F)
850	37.78°C (100°F)	29.44°C (85°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	37.78°C (100°F)	29.44°C (85°F)

TABLE V. TIMER EVALUATION

Dial Setting	Average Stopwatch Time	Difference
5	4 min - 44 sec	- 16 sec
10	9 min - 38 sec	- 22 sec
15	14 min - 44 sec	- 16 sec

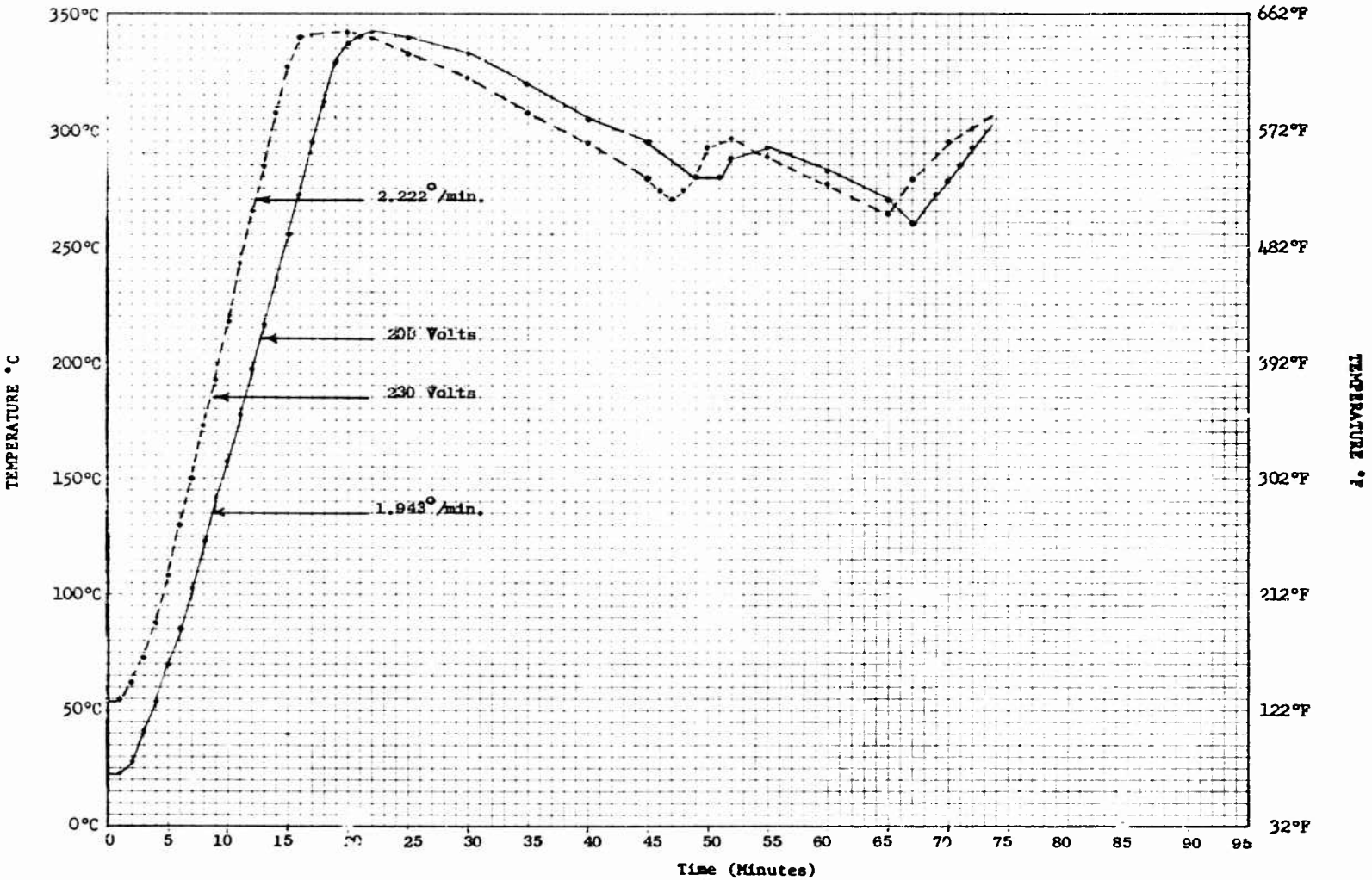

Figure 4. Heat-up Time and Temperature for 208 Volts and 230 Volts.

(2) Initial Heat-Up Time

The average initial heat-up times were found to have a linear relationship with the settings, i.e., the heat-up time for 350, 500, and 750 were in approximately the same proportions as the respective settings (Table III).

(3) Outer Surface Temperatures

The maximum temperature of any of the seven locations never exceeded 37.8°C (100°F) at any of the thermostat settings of 350, 500, and 750, or at the cleaning cycle setting of 850.

(4) Timer Accuracy

The timer was off 16 seconds at the 5- and 15-minute setting and 22 seconds at the 10-minute setting. The timer was difficult to set accurately only because of the knob design. It is, however, accurate enough for use with the cooking charts.

(5) Controls

No malfunction was detected in the proper operation of the thermostat signal light, the on-off switch signal light, or the on-off switch.

(6) Voltage Comparison

There was very little difference recorded for oven temperatures and heat-up times at either 208 volts or 230 volts. The comparison is shown on Figure 4.

4. Food Production

a. Commercial Convenience Food Evaluation:

(1) The following convenience food products were purchased in 30.48 cm (12 in.) long by 25.4 cm (10 in.) wide by 3.81 cm (1 1/2 in.) deep (half-size) disposable aluminum pans. Product net weight was 1.8144 kg (64 oz.).

Pronto Beef Stew*
Pronto Macaroni and Cheese*
Uncle Ben's Spanish Rice with Sausage**

*Products processed by Pronto Foods, Chicago, Illinois.
**Products processed by Uncle Ben's Inc., Houston, Texas.

(2) In three separate tests, one pan of each product was thawed in the oven and three probes from a Honeywell No. 112 Recorder were inserted into each product in the center, front center, and back center. The probes were suspended from the inside of the pan cover. Each product was refrozen then allowed to attain a test input temperature of 1.67°C (35°F) under refrigeration. Manufacturer's literature of commercial food testing results supplied with the oven was based on the use of full-size pans. However, since each of the foods evaluated was procured in half-size pans and each pan was placed on the right-hand side of the oven, a dummy load of 2.722 kg (6 lbs) of rolled oats (quick-cooking type) at -17.78°C (0°F) to -12.22°C (10°F), also in half-size pan, was placed on the left-hand side of the oven cavity to simulate a full oven load.

(3) The oven temperature was set at 750 and a preheat time of 20 minutes was selected. Product input temperature was 1.67°C (35°F) for all three products. The product was covered until the internal temperature probe of the slowest point reached 37.78°C (100°F). The cover was then removed, the product stirred, and reheating finished with the cover loosely set.

b. Armed Forces Recipe Test:

(1) No commercially prepared products were available in 6.35-cm (2 1/2-in.) deep, half-size disposable inserts (standard for centralized food preparation concept) so two Armed Forces menu items were prepared to provide a comparison with test results from a commercial testing agency. Oven temperature was set at 750.

(2) The first menu item was beef stew, recipe number L-22, and the second menu item was macaroni and beef casserole, recipe number L-24. Product input temperature was -18.7°C (-2°F) for beef stew and -13.89°C (7°F) for macaroni and beef casserole. The product was covered and stirring was done as stated in 4.a.(3).

(3) A comparison between the commercial test results and the results of this evaluation are shown in Table VI.

c. Oatmeal Evaluation and Comparison:

(1) Two standard oatmeal tests were performed to compare the reheating qualities of the radiant-heat quartz oven with electric convection ovens previously tested at the U. S. Army Natick Laboratories. One probe from a Honeywell No. 112 Recorder was inserted into the center of the product of each of four pans prior to freezing. Pans were half-size 6.35 cm (2 1/2 in.) deep, disposable inserts with 2.722 kg (6 lbs) of rolled oats (quick-cooking type). Each test was performed with two pans and an input temperature of -18.89°C (-2°F) for test number 1 and -8.89°C (16°F) for test number 2 (see 5.c.). Oven temperature was set at 750 and pans were covered. No stirring was performed during these tests or during the tests previously conducted with convection ovens.

TABLE VI. COMMERCIAL PRODUCTS AND ARMED FORCES RECIPE COMPARISON

Commercial Products	Pan Size	Product Input Temperature	Weight	Cooking Time
Macaroni & Beef Casserole	Full-size pans measuring	-23.33°C (-10°F)	4.536 kg (10 lbs)	31-35 min
Beef Stew	30.48 cm x 50.8 cm x 6.35 cm (12 in. x 20 in. x 2 1/2 in.)	-23.33°C (-10°F)	(No weight given) 5.673 liters (1 gal 2 qts)	45 min
Armed Forces Recipes				
Macaroni & Beef Casserole	Half-size pans measuring	-13.89°C (7°F)	3.856 kg (8 lb 9 oz)	19.5 min
Beef Stew	30.48 cm x 25.4 cm x 6.35 cm (12 in. x 10 in. x 2 1/2 in.)	-18.89°C (-2°F)	3.405 kg (7 lb 8 oz	59 min

5. Food Production Findings

a. Convenience Food:

There was a considerable variance in temperatures within individual pans of the beef stew and Spanish rice products. When the slowest probe reached 37.78°C (100°F) and the product was uncovered to be stirred, parts of the serving were cold. The first probe reached 71.6°C (161°F) in the beef stew at about 7 1/2 minutes, while the slowest probe was only 36.7°C (98°F), a variance of 63 degrees. The first probe reached 71.2°C (160°F) in the Spanish rice at about [illegible] minutes, while the slowest probe was 28.8°C (84°F). This was a variance of 76 degrees within the same pan. When the slowest probe reached 71.2°C (160°F) there were about 45 degrees difference between the slowest and the fastest probes. The temperature of 71.2°C (160°F) for the slowest probe was attained before the twenty-minute period but an even temperature throughout the pan required approximately twenty minutes. In the test of the stew and the rice, this even temperature was achieved when all 3 probes levelled off at 98.8°C (210°F). There was no sticking or burning of the product to the pan during the test. Internal temperature of the potatoes in the stew was taken immediately after taking the pan from the oven and varied from 69°C (156.2°F) to 86°C (186.8°F). Product temperature and reheat times are shown on Figures 5, 6, and 7 for all three probes.

b. Armed Forces Recipes:

Even though product temperature was recorded at 71.2°C (160°F) forty-five minutes after the reheating start for the beef stew, it could not be stirred because parts were still frozen while other parts were 71.2°C (160°F). The increase in reheating time for the Armed Forces Recipe is justified because of the increased food product weight of half-size pans, and test personnel judged that the commercial test results are valid (Table VI).

c. Oatmeal Evaluation:

Product appearance was good with slightly browned surfaces. There was a slight crusting with minimal drying on the outside edges. Test results are shown on Tables VII and VIII and Figures 8 and 9. Comparison of average reheating times between the radiant heat oven and electric convection ovens previously subjected to the standard oatmeal test are as follows:

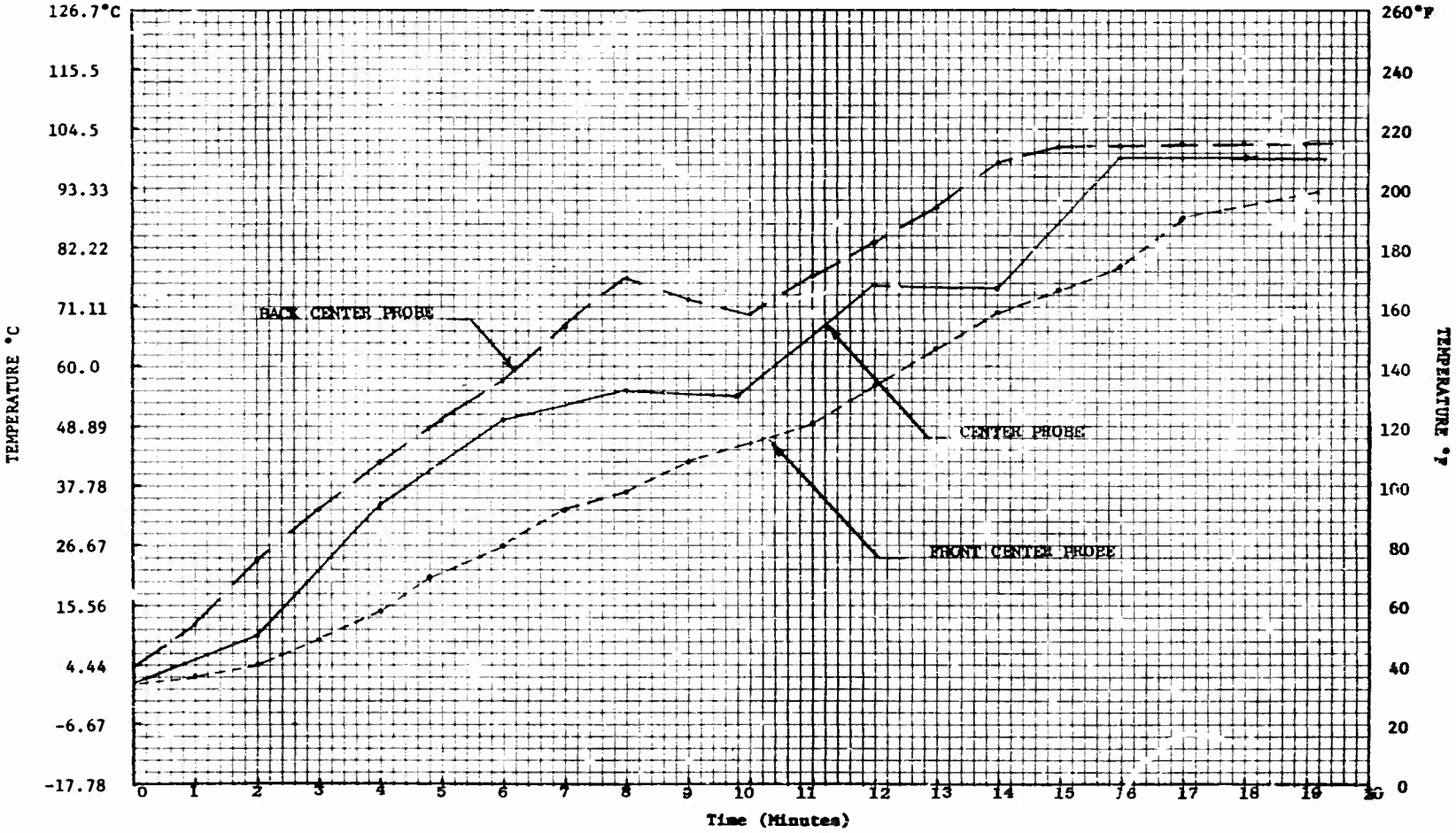

Figure 5. Reheat Temperature and Time, Pronto Beef Stew.

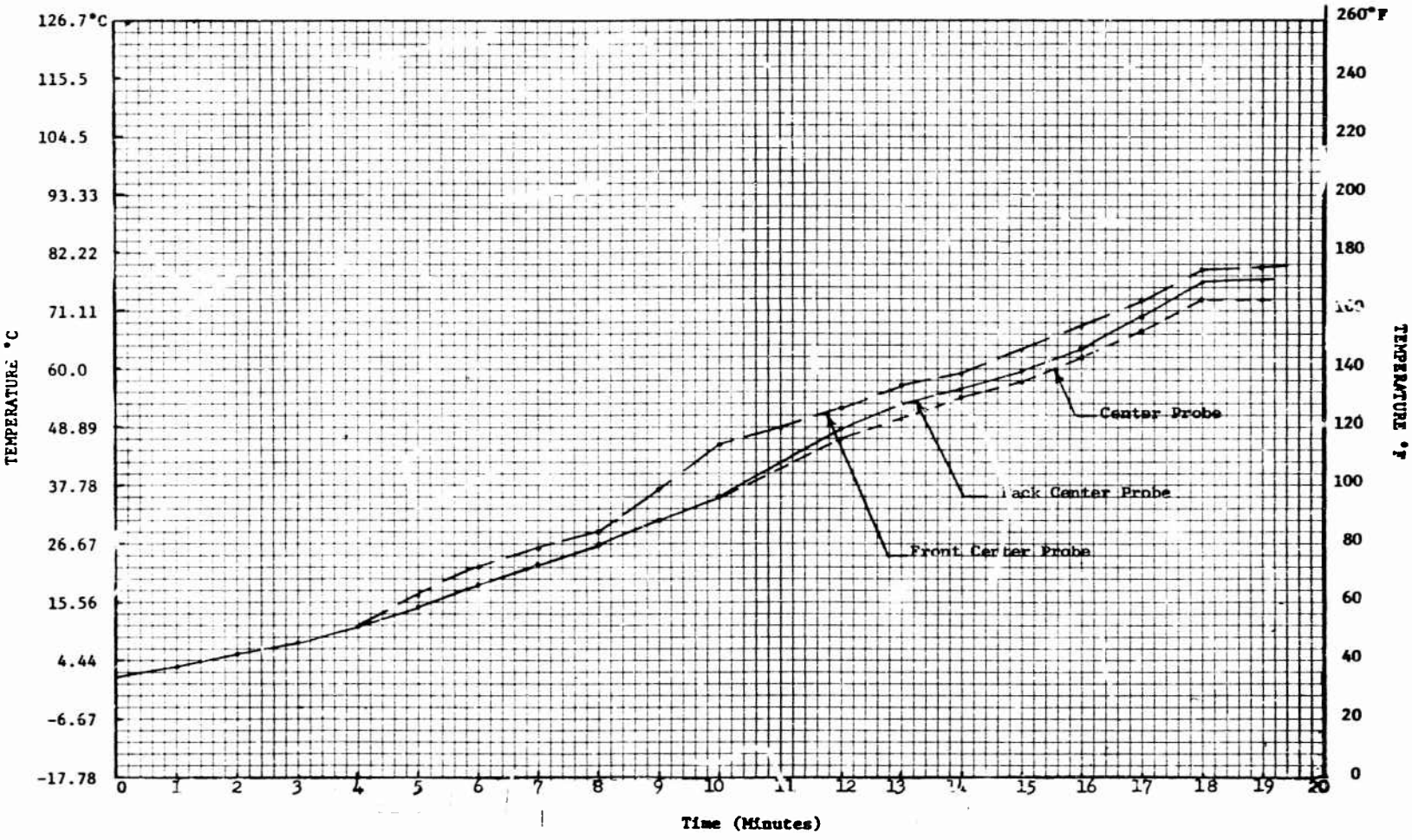

Figure 6. Reheat Temperature and Time, Pronto Macaroni and Cheese.

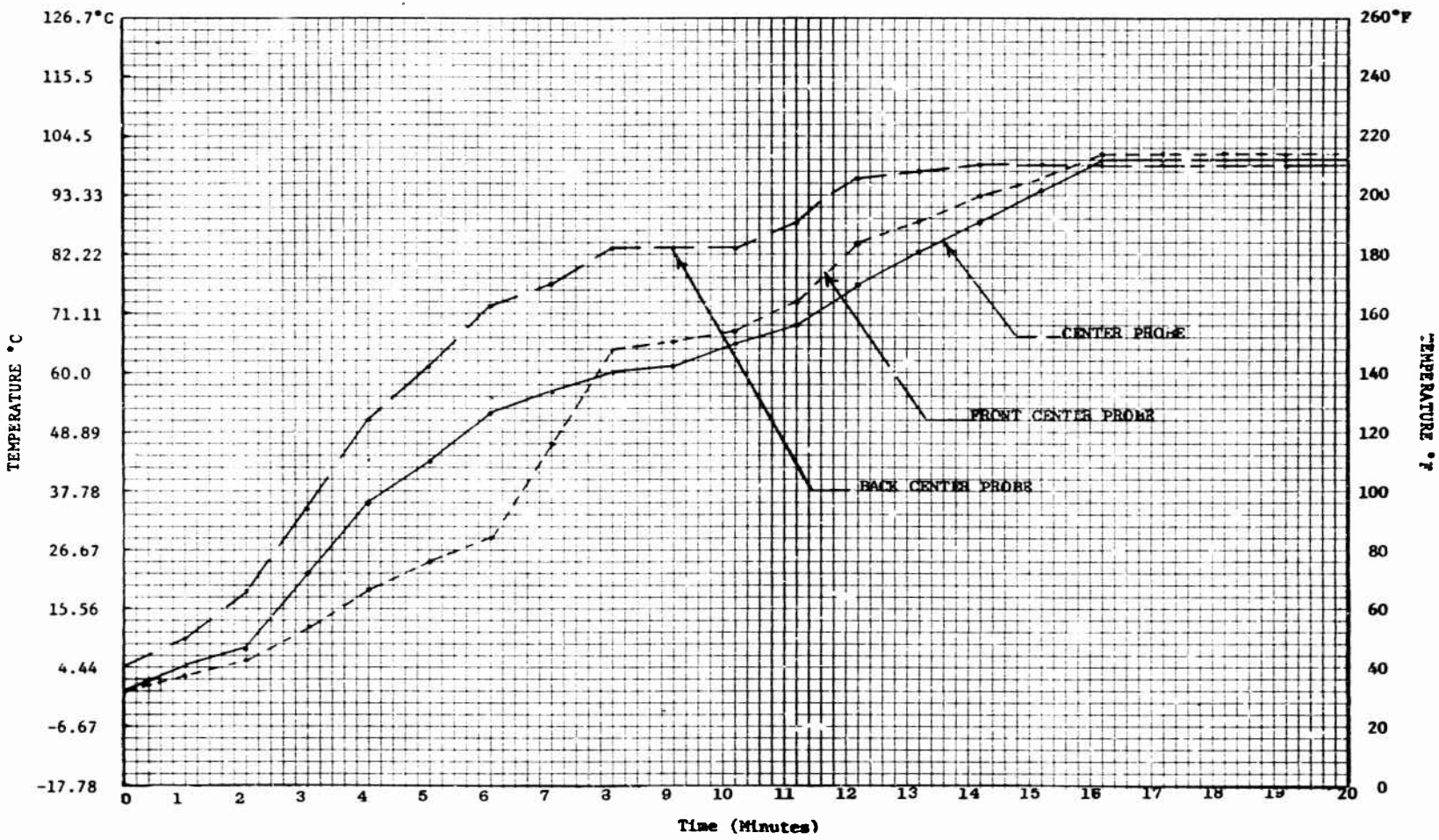

Figure 7. Reheat Temperature and Time, Uncle Ben's Spanish Rice and Sausage.

TABLE VII. TEST NO. 1, OATMEAL

	Fastest	Slowest
Probe number	2	1
Pan location in oven	Left	Right
Initial product temperature	-8.89°C (16°F)	-4.5°C (24°F)
Time to 0°C (32°F)	12 min	15 min
Interval from 0°C (32°F) to: 4.44°C (40°F)	2 min	1 min
37.78°C (100°F)	17 min	34 min
71.11°C (160°F)	45 min	53 min
Total time from initial temp. to 71.11°C (160°F)	57 min	68 min
Temp. of slowest probe when fastest is 71.11°C (160°F) *	--	53.4°C (128°F)
Temp. of fastest probe when slowest is 71.11°C (160°F) *	84.5°C (184°F)	--

*Time when fastest probe reached 71.11°C (160°F) to time when slowest probe reached 71.11°C (160°F) was 10 minutes.

TABLE VIII. TEST NO. 2, OATMEAL

		Fastest	Slowest
Probe number		2	1
Pan location in oven		Left	Right
Initial product temperature		-18.33°C (-1°F)	-18.89°C (-2°F)
Time to 0°C (32°F)		25 min	25 min
Interval from 0°C (32°F) to:	4.44°C (40°F)	14 min	14 min
	37.78°C (100°F)	34 min	46 min
	71.11°C (160°F)	49 min	64 min
Total time from initial temp. to 71.11°C ((160°F)		74 min.	89 min
Temp. of slowest probe when fastest is 71.11°C (160°F) *		--	42.78°C (109°F)
Temp. of fastest probe when slowest is 71.11°C (160°F) *		88.33°C (191°F)	--

*Time from when fastest probe reached 71.11°C (160°F) to time when slowest probe reached 71.11°C (160°F) was 15 minutes.

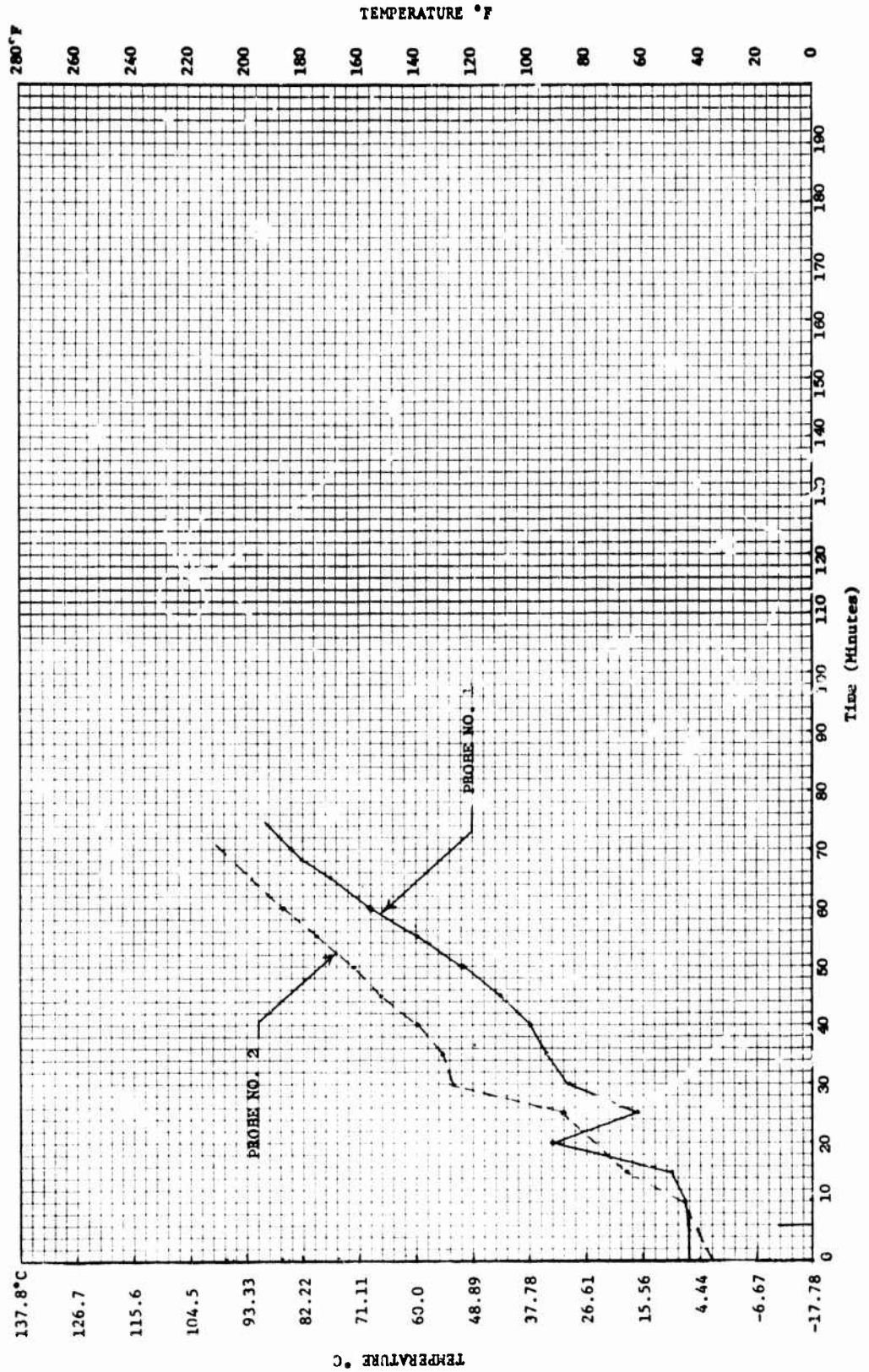

Figure 8. Reheat Temperature and Time, Oatmeal Test No. 1.

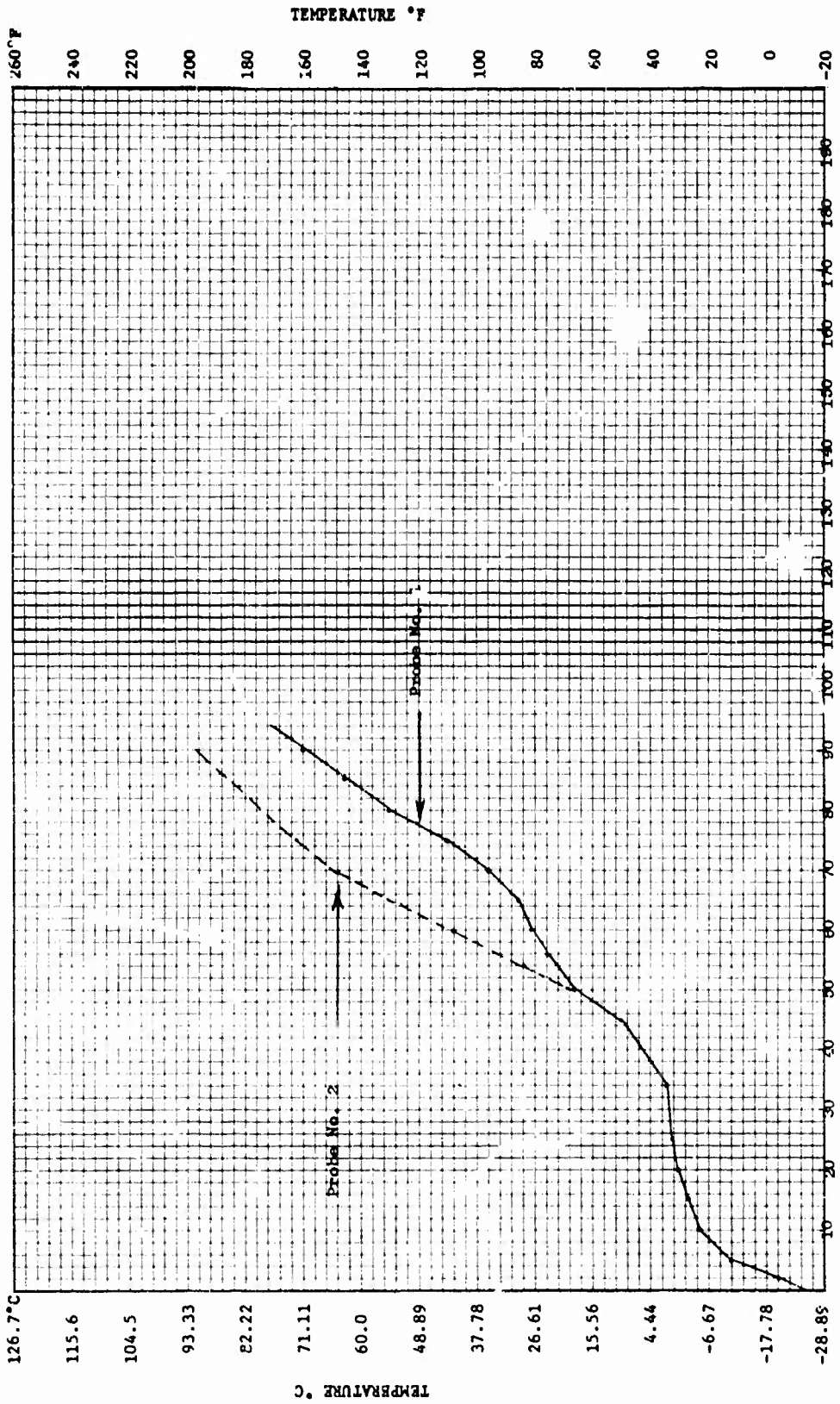

Figure 9. Reheat Temperature and Time, Oatmeal Test No. 2.

Convection Ovens			Radiant Heat Quartz Oven
Model A	Model B	Model C	
166 min	148 min	285 min	82 min

6. Safety

There were no safety hazards noted and equipment need not be constantly monitored. The oven bears the Underwriters' Laboratories (UL) Seal of Approval.

7. Sanitation

Cleaning was easily accomplished in accordance with the manufacturer's instructions. The self-cleaning feature functioned satisfactorily. The oven does not bear the National Sanitation Foundation Seal of Approval.

8. Conclusions

The oven is considered acceptable for use in the satellite dining facilities of the centralized food preparation system concept. The oven satisfactorily reheats prepared food items in small quantities in less than half the time required in large capacity convection ovens. Products heat best when stirred about halfway through the reheating time. For most efficient use, product depth should not exceed 5.08 cm (2 in.). Caution must be used in proper timing of different menu items to insure that even heat is obtained. Efficient reheating of a variety of items will depend on properly timed reheat periods and/or the expertise of the operator. The evaluation generally confirmed the findings of commercial food testing agencies: that products in half-size, 3.81-cm (1 1/2-in.) deep pans require approximately 20 minutes to reheat to an even internal temperature of over 71.2°C (160°F). Electrical components are wired in a safe manner. The oven is designed so it can be easily cleaned.